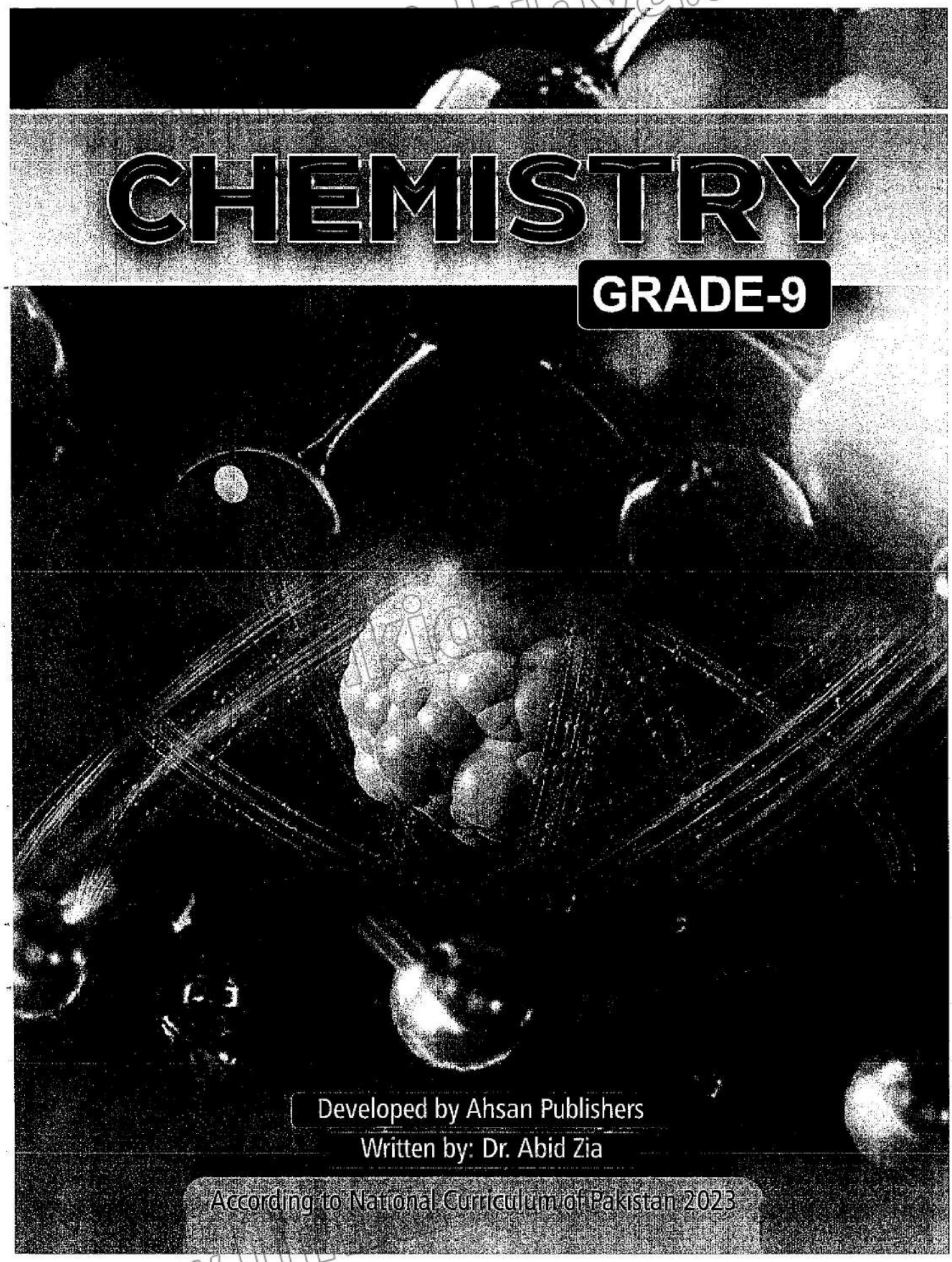

CHEMISTRY

GRADE-9

Developed by Ahsan Publishers

Written by: Dr. Abid Zia

According to National Curriculum of Pakistan 2023

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Contents

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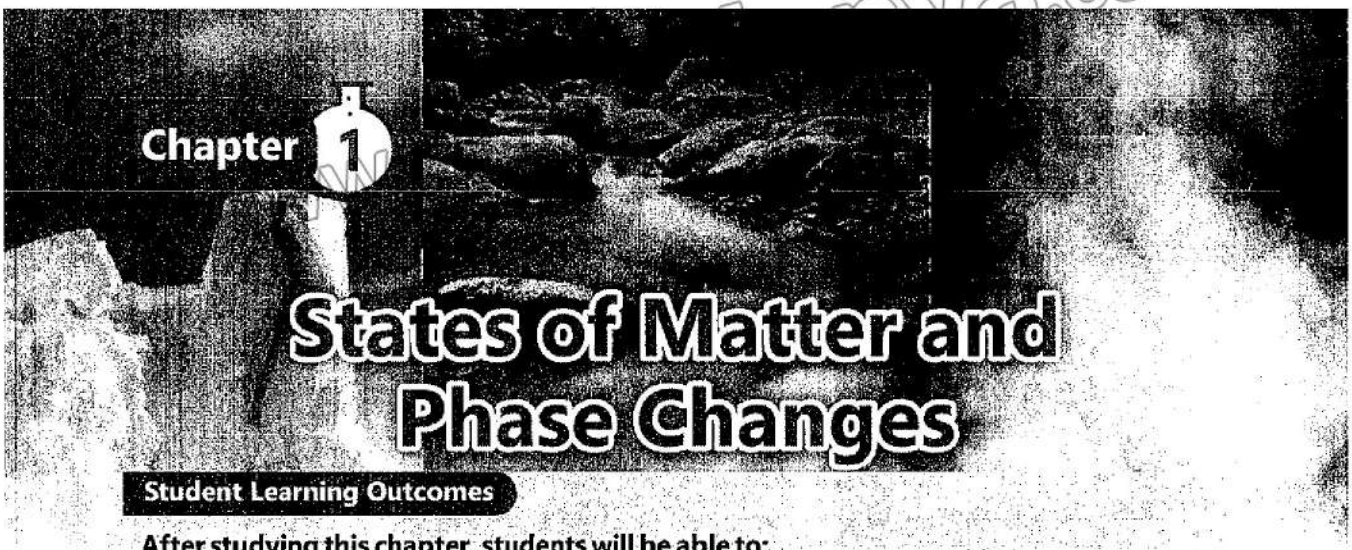

Chapter 1

States of Matter and Phase Changes

Student Learning Outcomes

After studying this chapter, students will be able to:

- Define chemistry as the study of matter, its properties, composition, and interactions with other matter and energy. Or Study of earth (solids), Air (gasses), Sea (liquids) and sky (plasma) and their interaction with each other.
- Explain with examples that chemistry has many sub-fields and interdisciplinary fields. Some examples include:
    - Biochemistry
    - Medicinal Chemistry
    - Polymer Chemistry
    - Geochemistry
    - Environmental Chemistry
    - Analytical Chemistry
    - Physical Chemistry
    - Organic Chemistry
    - Inorganic Chemistry
    - Nuclear Chemistry Astrochemistry)
- Define matter as a substance having mass and occupying space.
- State the distinguishing macroscopic properties of commonly observed states of solids, liquids and gases in particular density, compressibility, and fluidity.
- Identify that state is a distinct form of matter (examples could include familiarity with plasma, intermediate states and exotic states e .g., BEC or liquid crystals)
- Explain the allotropic forms of solids (some examples may include diamond, graphite, and fullerenes)
- Explain the difference between elements, compounds and mixtures
- Identify solutions, colloids, and suspensions as mixtures and give an example of each
- Explain the effect of temperature on solubility and formation of unsaturated and saturated solutions

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1.1 What is Chemistry?

Chemistry is the science which deals with the properties, composition and the structure of substances. It also studies the physical and chemical changes in matter and the laws or principles which govern these changes.

Determination of composition represents finding out percentages of elements and compounds in a sample of matter. Structure of matter means the arrangement of atoms in matter. Both physical and chemical changes may be brought about by the interaction of energy.

Branches of Chemistry

To understand the widely spread complex subject of chemistry and to concentrate on its specific aspects, chemistry is divided into many distinct branches. These branches have distinct areas of study for the scientists to focus on and to achieve breakthroughs and advancements.

1.Physical Chemistry

This branch investigates how substances behave at atomic or molecular levels. It provides clear explanation as to how fundamental physical laws governing our world cause atoms and molecules to show specific characteristics and in turn react to give huge structures related to life. Physical chemistry is also used to predict and change the rates of reaction and thus optimize the conditions to carry out the reaction on industrial scale.

2. Inorganic Chemistry

It is the study of the synthesis and properties of compounds that do not contain carbon hydrogen bonds. An inorganic compound can be composed of metals, nonmetals or a mixture of these, salts, acids and bases. Inorganic compounds are used as fuels, medicines, catalysts, pigments, surfactants, coatings and much more.

3. Organic Chemistry

It is the branch of chemistry that deals with the carbon compounds other than its simple salts like carbonates, oxides and carbides. In this branch, we study the structure, formation, properties, composition and reactions of carbon-containing compounds. Organic compounds are found in all forms of life and are also essential for life.

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4. Environmental Chemistry

It is the scientific study of the chemical and biochemical phenomena that occur in this planet. In this subject, we study the sources, reactions, effects and fates of chemical species in the air, soil and water environments. Without this, it would be impossible to study the effects humans have on the environment through the release of chemicals. It helps in understanding the causes, effects and solutions of different types of pollution.

5. Analytical Chemistry

This branch of chemistry deals with the analysis of different substances. It involves separation, identification and determination of the concentration of the material things. Nowadays the field of analytical chemistry generally involves the use of modern and sophisticated instruments to analyze the matter.

6. Biochemistry

It is the branch of chemistry in which we understand life through chemical processes. It is the study of chemical substances and vital processes occurring in living organisms. Biochemistry provides insights into the structure and function of molecules such as proteins, carbohydrates, lipids and nucleic acids.

7. Nuclear Chemistry

Nuclear chemistry deals with the reactions taking place in the nucleus of an atom. It deals with radioactivity, nuclear processes and transformation in the nuclei of atoms.

8. Polymer Chemistry

Polymers are large molecules made by linking together a series of building blocks. Polymer chemistry focuses on the properties, structure and synthesis of polymers and macromolecules. Many materials present in the living organisms including proteins, cellulose and nucleic acids are naturally occurring polymers.

Interesting Information!

Geothermal heat pump uses a pump to transfer underground water into the buildings during the winter to heat them and in the summer to cool them.

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9. Geo Chemistry

The study of chemical composition of Earth and its sources and minerals is called geo chemistry. Apart from its use in minerals exploration, geochemical mapping today has applications in environmental monitoring, forestry and medical research.

10. Medicinal Chemistry

In this branch of chemistry, the chemist tries to design and synthesize a medicine or a drug which is beneficial for mankind. It includes the discovery, delivery, absorption and metabolism of drugs in human body.

11. Astrochemistry

It is the study of molecules and ions recurring in space and interstellar space. In this discipline we study the abundance and reactions of molecules and ions in the universe and interaction of these species with radiation.

Exercise

A lunar mission has recently brought samples from the Moon. The following experiments were then carried out on it. Point out the branch of chemistry these experiments are related to.

Experiment	Branch of Chemistry
1. Determing its composition	
2. Studying the physical properties of materials it contains	
3. Carrying out chemical reactions with usual inorganic reagents	

1.2 States of Matter

This world is made up of matter and energy. Energy is non-material in nature. Anything other than energy which carries weight and occupies volume is called matter. We encounter material things everywhere in all sort of different and distinct forms.

A state of matter is one of the many distinct forms in which matter can exist. We observe four states of matter in everyday life: solid, liquid, gas and plasma. Apart from these, there are more states of matter which we do not see in our everyday life.

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The three primary states of matter are the solid, liquid and gaseous. They are different from each other due to different strength of intermolecular forces, the arrangement of particles and the distance between the particles. In gases, molecules are very widely apart with no order whatsoever and very weak intermolecular forces. All these features make gases easily compressible. Their densities are obviously very low.

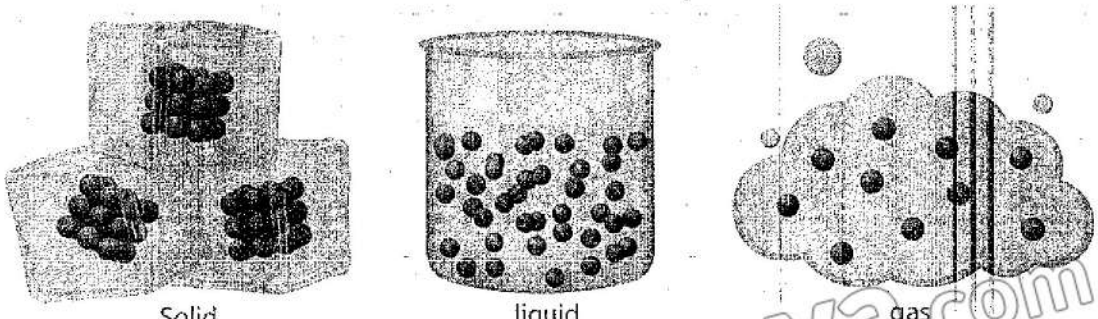
The liquids, on the other hand, have molecules closely attached but randomly arranged and there exists significant intermolecular forces between them. Liquids are therefore not easily compressible and their densities have higher values than those of gases.

Solids have a definite shape and a fixed volume. Particles in solids are closely packed and have very strong interatomic or intermolecular attractions. The particles in solids remains fixed at their positions where they can oscillate about their mean positions. Solids are incompressible and rigid.

The densities of solids are very high. Solids are the only state of matter which do not need any container to be stored. In crystalline solids, particles are perfectly arranged and strongly bonded. This makes them almost incompressible. They are the most dense substances.

Plasma is not so generally seen form of matter. It is composed of particles with very high kinetic energy. It exists in fluorescent tubes, lightning and welding arcs. Plasma can be considered as a partially ionized gas containing electrons, ions, photons, etc.

Matter also exits in intermediate states where liquid meets gas and liquid meets solid, for example supercritical fluids, liquid crystals and graphene. Supercritical fluids are highly compressed states which show both properties of gases and liquids. Chemical reactions which may not be carried out in conventional solvents, may possibly be carried out in supercritical carbon dioxide.



Solid liquid gas

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Liquid crystal is a state of matter whose properties are between those of conventional liquids and those of crystalline solids. Liquid crystals are used in display devices including computer monitors, clocks, watches and navigation systems. Graphene is an example of two-dimensional crystal, a single layer of carbon atoms arranged in a hexagonal pattern. Graphene is a tough, flexible and light material with a high resistance.

States of matter that are not commonly encountered are called exotic states of matter. Examples are dark matter, Bose-Einstein condensate, nuclear matter, quantum spin liquid and many others.

1.3 Element, Compound and Mixture

Matter in this world exists in the form of elements, compounds and mixtures. Element is the simplest form of matter. It is a pure substance containing the same kind of atoms. It cannot be broken down into simpler substances by ordinary chemical reactions. Elements exist in all three forms; solid, liquid and gas. Most of the elements found in this world exist in solid form. Liquid and gaseous elements are very few in number as compared to solids.

Elements may be a metal, a non-metal and a metalloid and a noble gas. Elements can also exist in form of atoms, molecules, ions and isotopes. Examples of important elements are sodium, potassium, magnesium, calcium, carbon, silicon, nitrogen, oxygen, chlorine, helium, copper, gold, zinc, silver nickel, cobalt, mercury, bromine iodine, etc.

Compound is also a pure substance. It is made up of two or more different chemical elements combined in a fixed ratio. When elements come together, they react with each other and form chemical bonds that are not easy to break.

Compound may be molecular, ionic, intermetallic and coordination complexes. Compounds may also be inorganic and organic in nature. Examples of important compounds are water, ammonia, methane, carbon dioxide, carbonates, chlorides, starch, proteins, carbohydrates, mineral acids, organic acids, etc.

The composition and properties of elements or a compound are uniform throughout a given sample and from one sample to another. A mixture is formed when more than one types of elements or compounds are mixed together in any ratio. Air, soil, milk and tap water are everyday examples of mixtures. A mixture may be homogeneous or heterogeneous. A solution of salt and water is an example of homogeneous mixture because its concentration is uniform throughout. A sample of rock is an example of heterogeneous mixture because

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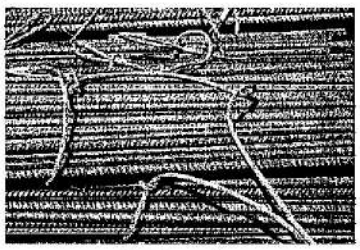
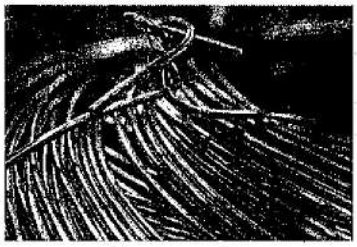
the concentrations of its constituents is different in its different parts. Rocks are composed of different types of minerals such as granite, mica and limestone.

Interesting Information!

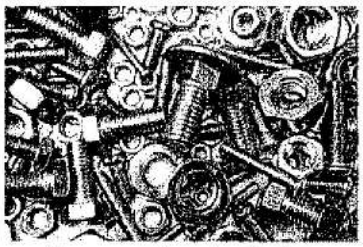
Many elements are found in nature but some are artificial. Technetium was first element created by scientists in the laboratory.



Iron rods

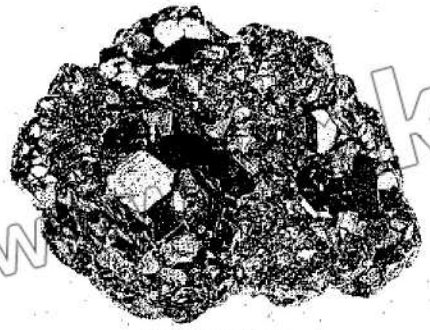


Copper wire

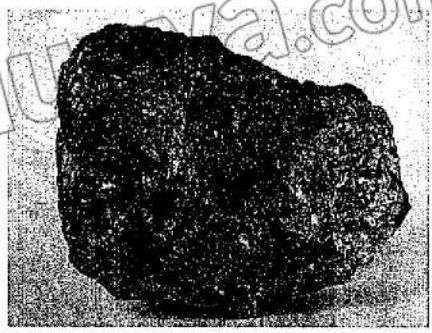


Screw and nuts of zinc

Fig (1.1): Elements

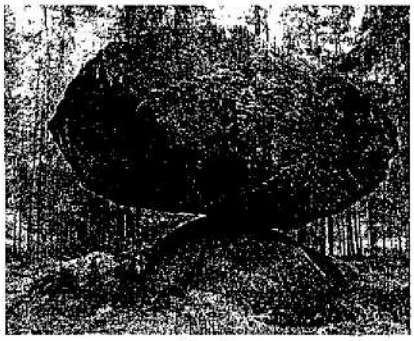


Iron sulphide

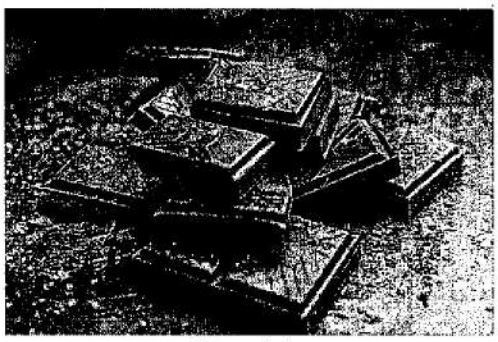


Copper sulphide

Fig (1.2): Compounds



Rock



Chocolate

Fig (1.3): Mixtures

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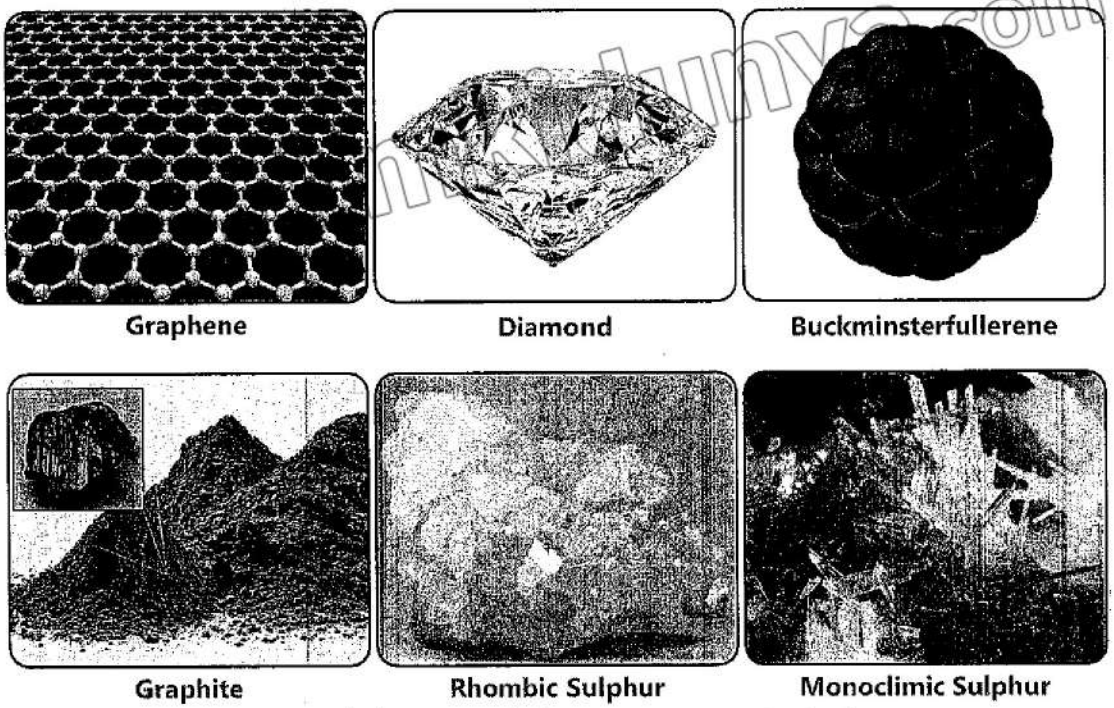
Allotropic Forms of Substances

Both elements and compounds may exist in more than one structural forms which can exhibit quite different physical and chemical properties. These forms are called allotropic forms and phenomenon is called allotropy. Element oxygen exists in two allotropic forms namely oxygen (O_2) and ozone (O_3).

Similarly, carbon exists in three main allotropic forms, diamond, graphite and Buckminster fullerene. Diamond has a giant macromolecular structure whereas graphite has a layered structure of hexagonal rings of carbon. Buckminster fullerene (C_{60}) consists of spheres made of atoms arranged in pentagons and hexagons. Fullerenes are stable at high temperatures and high pressures. Being covalent in nature, they are soluble in organic solvents. The fullerene structure is unique in that the molecule is not charged, has no boundaries and has no unpaired electrons. They have a cage like structure. Fullerene C_{60} has a low melting point. It is soft and cannot conduct electricity. Element sulphur also exists in two crystalline allotropic forms i.e. rhombic and monocline; the former is more stable than the latter.



Graphene | Diamond | Buckminsterfullerene

Graphite | Rhombic Sulphur | Monoclimic Sulphur

Fig (1.4) Allotropic Forms of Carbon and sulphur

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Differences between Elements, Compounds and Mixtures

Elements	Compounds	Mixtures
An element is the simplest form of matter. It is a pure substance containing the same kind of atoms.	A compound is a pure substance. It is formed by the chemical combination of two or more atoms of different elements.	Mixture is an impure compound. A sample of matter having more than one type of elements or compounds mixed together in any ratio, is called a mixture.
It is not possible to break down an element into simpler particles by ordinary chemical reactions.	In a compound, the atoms of elements must combine together by a fixed ratio by weight. For example, in water (H_2O) hydrogen and oxygen are present in a fixed ratio of 1:8 by weight.	Each component of a mixture retains its identity and specific properties.
When an element exists in the form of aggregate of atoms, it is represented by a symbol. For example, sodium and calcium are represented by their symbols Na and Ca.	It is possible to break a compound into its constituent elements by a chemical reaction. For example, ammonia can be converted back to nitrogen and hydrogen by a suitable chemical reaction.	A mixture may be homogeneous or heterogeneous. For example, the solution of common salt in water is a homogeneous mixture while a sample of rock is a heterogeneous mixture.
Gaseous elements exist in the form of independent molecules, for example nitrogen (N_2), oxygen (O_2) and chlorine (Cl_2). Noble gases, however, exist as mono atomic molecules.	The properties of a compound are always different from the elements from which it is formed. For example, the properties of water are different from those of hydrogen and oxygen.	The components of a mixture are not chemically bound together and they can be separated by physical methods.

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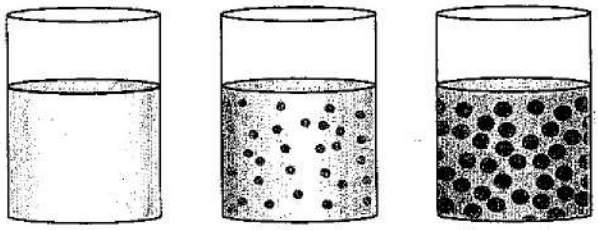
	Compounds exist in the form of molecules, for example hydrogen chloride (HCl), ammonia (NH_3) and water (H_2O). Compounds may also exist as network arrangement of their atoms. For example, ionic compounds like NaCl and covalent compounds like sand (SiO_2).	The properties of a mixture are the sum of those of its components.

Exercise

1. Which elements are found in pure state in Earth?
2. Which elements are in very small amounts in Earth?

1.4 Solution, Colloidal Solution and Suspension

A solution is such a mixture in which solute particles are completely homogenized in the solvent e.g. dissolution of sodium chloride or copper sulphate in water. The solute particles in such a solution cannot be seen by the naked eye. If solution is filtered, these particles pass through the pores of filter paper leaving no precipitate. Such a solution is called a true solution. A suspension, on the other hand, is a mixture in which solute particles do not dissolve in the solvent. We can actually see these particles. If a suspension is kept for some time, these particles settle down. Again, if this suspension is filtered, the particles in it cannot pass through the pores of filter paper and can be collected as a precipitate. A mixture of chalk in water is an example of suspension.



Solution Colloidal Suspension

Besides a true solution and a suspension, there is a third form of solution called colloidal solution. In this type, the solute particles do not homogenize with solvent. These particles are a little bit bigger than the solute particles present in the true solution but not big enough to be seen with a naked eye like the particles present in a suspension. If kept for some time, the particles of a colloidal solution do not settle down. On filtration, these particles pass through the filter paper like

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the particles of a true solution. Starch solution and white of an egg are the common examples of colloidal solutions.

Formation of Unsaturated and Saturated Solutions

Take about 100 g of water in a beaker, add to it 5g of table sugar, and stir it. The sugar will dissolve in water. Then add another 5g of sugar and stir. This will also dissolve. This solution is called an unsaturated solution. A solution which can dissolve more amount of a solute at a particular temperature is called an unsaturated solution. Continue adding sugar in the above solution. As the quantity of sugar in water increases, its dissolution will become more difficult. A stage comes when no more sugar will dissolve in water at this temperature. Any more sugar added at this stage will settle down at the bottom of the beaker. This solution is called a saturated solution at a particular temperature of the process.

A solution in which the maximum amount of the solute has been dissolved in a particular amount of a solvent at a particular temperature is called a saturated solution.

Different solutes have different solubilities in a particular solvent. For example, if the saturated solutions of table sugar and sodium chloride are prepared, it is found that the concentration of sodium chloride saturated solution is 5.3 molar at room temperature while that of sugar solution is 3.8 molar at room temperature. In other words, the solubility of sodium chloride in water is far greater than that of sugar at room temperature. This is due to the fact that the attraction of sodium and chloride ions with water are far stronger than the attractions between sugar molecules with water.

How formation of solution can be useful in daily life?

Interesting Information!

Solutions are closely related to our everyday lives. The air we breathe, the liquid and other foods we consume, the fluids in our body, the solids like steel we use, are all solutions.

Effect of Temperature on the Solubility of Solutes

The solubility of a solute is the amount of solute which can dissolve in 100g of a solvent at a particular temperature.

Change in temperature has different effects on the solubility of different compounds. Usually the solubility increases with the increase in temperature but it cannot be taken as a general rule. There are a large number of compounds whose solubility in H_2O increases with the increase in temperature e.g. potassium

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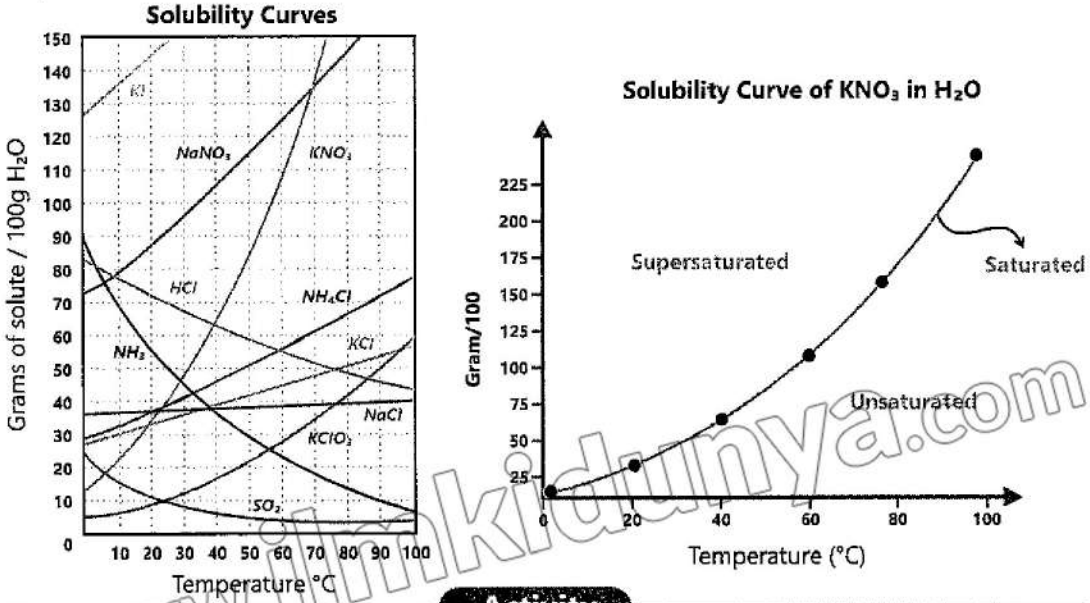
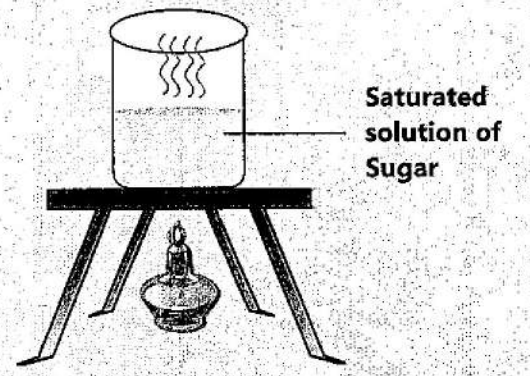
nitrate (KNO_3), silver nitrate ($AgNO_3$) and potassium chloride (KCl) etc. The solubility of sodium chloride in H_2O does not increase appreciably with the increase in temperature. The solubility of compounds like lithium carbonate (Li_2CO_3) and calcium chromate ($CaCrO_4$) decreases with the increase in temperature. The solubility of gases in water also decreases with the increase in temperature.



Activity

Take 100 g of water in a beaker and prepare saturated solution of sugar at room temperature. Heat the beaker on a spirit lamp. Add a little more sugar in it and stir it. Will this sugar be dissolved in it? You will notice that by heating the solution the quantity of sugar dissolved in water has increased i.e. the solubility of sugar has increased.



Similarly, the solubilities of copper sulphate and sodium nitrate also increase with increase in the temperature. However, the solubility of calcium hydroxide decreases with the increase in temperature.

Exercise

How variation of solubility at different temperatures can be useful for us?

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Interesting Information!

1. The increase in the solubility of solids in liquids with increase in temperature may be used to purify them. Pure solids commonly appear as beautifully shaped crystals.

Crystals of Potassium Nitrate

2. Generally the solubility of gases decreases with increase in temperature. Carbon dioxide gas is also more soluble in water at low temperature. Soda water bottles are thus stored in the refrigerator to keep carbon dioxide gas dissolved in water for a longer period of time.

Key Points

1. Chemistry is that branch of science which deals with the composition of matter, changes in matter and the laws which govern these changes.
2. To understand the vast and complex subject of Chemistry, it is divided into many branches. Physical chemistry, inorganic chemistry and organic chemistry are its main branches among so many others.
3. Matter exists mainly in three states: solid, liquid and gas. They are different from each other due to different characteristics of particles which they contain.
4. Plasma is regarded as the fourth state of matter which is not normally observed in this world. Most of the matter present in the rest of the universe exists in this state.
5. Matter also exists in the intermediete states which are at the borderline of its two principal states, between liquid and gas or between liquid and solid. Supercritical fluids and liquid crystals are some examples of such states.
6. Matter exists in the form of distinct entites called elements, compounds and mixtures.
7. Elements, compounds and mixtures have distinct properties individually and they are very different form one another.
8. Solutions, suspensions and colloidal solutions are different forms in which the mixtures usually exist. They have their own characteristic properties.

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Exercise

1. Tick (✓) the correct answer.

(i) Matter is present in neon signs in the state of:

(a) Supercritical fluid (b) Plasma

(c) Gas (d) Liquid crystal

(ii) Hazardous effects of shopping bags are studied in:

(a) Geochemistry (b) Inorganic chemistry

(c) Analytical Chemistry (d) Environmental chemistry

(iii) The man-made polymer is:

(a) Starch (b) Polystyrene

(c) Protein (d) Cellulose

(iv) The allotropic form of sulphur is:

(a) Brass (b) Rhombic

(c) Graphite (d) Bronze

(v) Which liquid among the following is a colloidal solution?

(a) Milk (b) Slaked lime used for white wash

(c) Vinegar solution (d) Mixture of AgCl in water

(vi) Which of the following is a heterogeneous mixture?

(a) A solution of calcium in hydroxide water

(b) A solution of potassium nitrate in water

(c) Hot chocolate

(d) Concrete mixture

(vii) A state of matter whose properties are between those of liquids and crystalline solids.

(a) Liquid crystal (b) Supercritical fluid

(c) Plasma (d) Dark matter

(viii) When the tiny particles of a substance are dispersed through a medium, the mixture is named as:

(a) True solution (b) Colloid

(c) Suspension (d) Heterogenous mixture

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(ix) A solution of $KClO_3$ has a solubility of about 13.2g per 100 cm^3 at 40°C. How its solubility will be affected, if you decrease the temperature?

(a) The solubility will increase

(b) The solubility will decrease

(c) The solubility will remain the same

(d) The solubility will first increase with temperature and then it will decrease

(x) You are studying the rate of hydrolysis of organic compound starch under different conditions of temperature. In which branch of chemistry this topic will fall?

(a) Organic Chemistry (b) Analytical Chemistry

(c) Biochemistry (d) Physical Chemistry

2. Questions for Short Answers

i. Why is there a need to divide Chemistry into many branches. Give three reasons.

ii. Reactions may take place due to electrons present outside the nucleus or they may take place inside the nucleus. Which branches of Chemistry cover these two types of reactions.

iii. What types of problems are solved in analytical chemistry?

iv. Both graphite and graphene have hexagonal layered structures. What is the difference?

v. Why are supercritical fluids important?

vi. In which state does matter exist in the Sun?

vii. What is the importance of graphene?

viii. Which form of matter do most of the material things in this world belong to?

3. Constructed Response Questions

i. How does a supercritical state look like?

ii. In what way is plasma created in a fluorescent tube?

iii. Most of the molecules we study in biochemistry are organic in nature. Where does the difference exist in organic and biochemistry branches of Chemistry.

iv. Give the reason of brilliance shown by diamond. Can you improve it?

v. Explain the dissolution of NaCl in water.

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vi. Why do different compounds have different solubilities in water at a particular temperature?

vii. Why NaCl can be crystallized from water just like KNO_3?

viii. Why graphite is slippery to touch which property of graphite enables it to be used as lubricant?

4. Descriptive Questions

i. Mention the name of the branch of Chemistry in which you will study each of the following topics.

(a) Rate of a reaction (b) Digestion of food in human body

(c) Properties of plasma (d) Ecosystem

(e) Reactions taking place during fire works

(f) Measurement of the absorption of wavelength with the help of ultraviolet spectrometer

ii. What are allotropic forms? Explain the allotropic forms of carbon and sulphur. How does coal differ from diamond?

iii. What are supercritical fluids. How are they different from ordinary liquids?

iv. Define solubility of a solute. How does the solubility of solutes change with the increase in temperature?

v. What types of movements are present in gaseous and liquid molecules?

vi. Differentiate between the areas which are studied under inorganic and organic chemistry.

5. Investigative Questions

i. Preparation of solutions leads to an important process in chemistry which enables us to purify a compound through crystallization. Describe a process in which potassium nitrate is purified by crystallizing it in water.

ii. Graphene is called a miracle material and it is the material of the future. Which of its many properties makes it very useful in electronics?

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